

LA-UR-14-28639

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Title:	Field Validation of Predicted Large Game Movement Corridors and Pinch Points at Los Alamos National Laboratory
Author(s):	Bennett, Kathryn Doris Hansen, Leslie Ann Robinson, Rhonda Jo
Intended for:	Report Environmental Programs
Issued:	2014-11-05 (rev.1)

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Field Validation of Predicted Large Game Movement Corridors and Pinch Points at Los Alamos National Laboratory



Prepared by: Kathryn D. Bennett, Operations Integration Office
Leslie A. Hansen, Environmental Stewardship Services
Rhonda J. Robinson, Environmental Compliance Programs

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ACRONYMS

ANOVA	analysis of variance
BRMP	Biological Resources Management Plan
DSA	Decision Support Application
ENV-ES	Environmental Protection Division – Environmental Stewardship Services
GIS	Geographic Information System
GPS	Global Positioning System
LANL	Los Alamos National Laboratory
MDA	Material Disposal Area
PIR	passive infrared
SD	standard deviation
TA	Technical Area
VHF	very high frequency

1.0 INTRODUCTION

Overall Purpose

In 2007, Los Alamos National Laboratory (LANL or the Laboratory) adopted a Biological Resources Management Plan (BRMP) that describes the Laboratory's goals, objectives, and strategies for managing biological resources (Hansen et al. 2007). One of the identified objectives is to maintain the ability of large game animals (including mule deer and Rocky Mountain elk) to migrate across LANL property. To achieve this objective, LANL is identifying locations of large game movement pathways across the landscape, and developing best management practices to maintain those pathways including recommendations to minimize the occurrence and severity of animal-vehicle accidents on LANL property.

Bennett (2006) modeled movement corridors for large game at LANL using Geographic Information System (GIS) analyses and Rocky Mountain elk telemetry data. By identifying large game movement corridors, LANL can better manage activities to facilitate wildlife movement to adjacent properties while minimizing adverse human-large game interactions. In preparation for this study, the movement corridor model was updated in 2011. Information from this study will feed into LANL management tools such as the Decision Support Application (DSA) spatial analysis tool and the Long-Term Strategy for Environmental Stewardship and Sustainability.

The overall purpose of this study was to test the real-world use of the locations identified as movement corridors and pinch points (areas of constricted movement around facilities and roads) by large game. We addressed this question in two ways: (1) a one-year camera study using detections of wildlife by trail cameras to compare use of pinch point areas to non-movement-corridor areas along Pajarito Road, and (2) an analysis of the location of animal-vehicle accidents relative to the predicted locations of large game movement corridors crossing Pajarito Road.

Specific Study Objectives:

- Test the animal movement model identification of movement corridors and pinch points for LANL.
- Compare accident locations to movement corridor and pinch point locations.
- Provide observations on seasonal animal use of the Pajarito Road area.

Previous Research on Rocky Mountain Elk and Mule Deer Habitat Use and Movements in the LANL Area

During the period of 1995 to 2003, several studies were conducted in the Los Alamos area on the survival, movements, and habitat use of Rocky Mountain elk using both very high frequency (VHF) and Global Positioning System (GPS) telemetry collars (Biggs et al. 1998, Wolf 2003, Bennett 2006, Biggs et al. 2010, Rupp and Rupp 2010, Hansen et al. 2012). In general, habitat selection studies documented that elk prefer grassland habitats (Biggs et al. 1998, Bennett 2006,

Biggs et al. 2010). Biggs et al. (2010) found that in some (but not all) seasons following the Cerro Grande fire, elk preferred areas that had been severely burned. Biggs et al. (1998) recorded most observations of elk on slopes of less than 20 degrees, and Bennett (2006) found that elk decreased their use of an area as the slope increased.

Biggs et al. (1998) documented 7 of 10 marked elk residing year-around on the Pajarito Plateau. Wolf (2003) found that elk wintering on LANL property remained primarily on LANL or at lower elevations in the Jemez District of the Santa Fe National Forest (in the American Springs area west of LANL) during non-winter months, while elk wintering on Bandelier National Monument property spent non-winter months at the Valles Caldera National Preserve or on the higher elevations of the Jemez District of the Santa Fe National Forest. Hansen et al. (2004), using spotlight survey data, documented elk on LANL property in both summer and winter, with a consistent increase each year of number of elk sighted per kilometer travelled in the summer during 2000 through 2003. Rupp and Rupp (2010) described elk in the Jemez as displaying “quasi-migratory” movements—seasonal home ranges were difficult to delineate but animals moved in response to the best resources available at the time. They observed an increase in movement activity in November and in April/May relative to other periods of the year.

Snow depth appears to be an important factor in elk movements in winter since 90 percent of all elk locations occurred in locations with snow depths of less than 8 centimeters (Rupp and Rupp 2010). Increased snowfall appears to push elk out of the higher elevations of the Jemez Mountains during wet winters. Increased numbers elk sightings in February during spotlight surveys on LANL property were correlated with higher levels of January snowfall (Hansen et al. 2004). Wolf (2003) found that the number of elk wintering on Bandelier National Monument was directly related to accumulated snow depths.

Less data is available for mule deer habitat use and movements. Hansen et al. (2012) documented extensive use of residential areas within the Los Alamos townsites by mule deer year-around, with deer crossing roads an average of two to seven times per day. Mule deer home ranges straddled highways as well as primary, secondary, and tertiary arterial roads. Bender et al. (2007) found that adult female mule deer in north-central New Mexico had annual survival rates ranging from 0.63 to 0.91 during 2002 through 2004. The most common cause of adult female mortality was starvation, and they estimated annual rates of population change ranging from -35 percent to +6 percent during this period. Given a lack of natural food sources, residential or commercial areas with irrigated landscaping and/or effluent outfalls are likely to be attractive to mule deer in a wildland-urban interface setting during periods with low precipitation.

Previous Research on Factors Influencing Animal-Vehicle Accidents in the LANL Area

Biggs et al. (2004) analyzed vehicle-accident data in the LANL area from 1990 through 1999 and examined landscape factors associated with accident sites. They found that locations that had a downward slope to the road and larger quantities of vegetation taller than 2 meters in height were more likely to be accident hotspots.

Hansen et al. (2012) found that deer vehicle-accident locations were only weakly correlated with the densities of recorded deer road crossings by telemetered deer. This was likely because accidents were rare on roads with low speed limits, while those roads were frequently crossed by deer.

Roadside visibility and speed limits apparently play as large or larger a role in animal-vehicle accident locations as the frequency of use of an area by large game. Frequency of animal-vehicle accidents in the Los Alamos region are significantly related to season and time of day, with the most accidents occurring during seasons of shorter day length, in the hours immediately following sunset (Biggs et al. 2004, Hansen et al. 2012). This represents the time of year when LANL's evening commuter traffic occurs after sunset; when there may be increased movement of large game animals during the breeding season; and when in some years large game animals may move onto the Pajarito Plateau from the Jemez Mountains in response to snowfall at higher elevations.

Elk Movement Model, Corridors, and Pinch Points

Bennett (2006) used GIS to integrate a habitat suitability model and a barrier model into a least-cost path model that predicts seasonal Rocky Mountain elk movement routes across the landscape. The habitat suitability model estimated how elk used resources within the study area by comparing elk locations from telemetry data to the availability of resources defined by random points within each home range. Biggs et al. (1998) defined five distinct seasons for elk as winter (November–February), spring (March–April), calving (May–June), summer (July–August), and fall (September–October). A predictive habitat suitability equation was developed through logistic regression for each season and a composite yearly equation was developed.

The barrier model was developed for features that act as physical barriers to elk movement such as buildings, fences (security and industrial), roads, steep slopes, and major water bodies. These features were weighted based on the amount of impedance they impose on elk movement. The habitat suitability model and the barrier model were combined to produce a cost surface. The cost surface represented a relative cost per cell for elk movement. Low cost cells (better habitat, fewer barriers) facilitate movement and high cost cells (less desirable habitat, more barriers) impede movement. The least-cost path movement model was developed within a raster environment with a grid cell resolution of 30 meter by 30 meter.

Elk movement corridors were defined using cost surfaces, source areas, and destination areas. Source and destination areas were identified from areas of frequent use by radio collared elk, with source areas being defined within LANL boundaries and destination areas in the neighboring properties of United States Forest Service, Bandelier National Monument, and Pueblo de San Ildefonso lands. Bennett (2006) defined movement corridors as 1,000-foot-wide least-cost pathways from source to destination areas.

For this study, Bennett updated her large game movement model in 2011–2012 by updating the barrier model with new LANL roads, facilities, and fences. After the barrier model was updated, a new cost surface was generated. Bennett also identified three areas along Pajarito

Road on LANL property as possible “pinch points.” Pinch points are sections of a movement corridor that are constricted due to topographical features or other physical barriers including fences and buildings. Pinch points were identified in movement corridors crossing Pajarito Road where the corridor was constricted or funneled along a steep canyon or drainage and was further constricted by buildings or security fences along the road.

2.0 STUDY AREA

Los Alamos is located in northern New Mexico, about 35 miles northwest of Santa Fe (Figure 1). LANL facilities can be found in 50 different work areas (called technical areas) that are spread across 36 square miles of the Pajarito Plateau. Pajarito Road is one of three major roads traversing southeast to northwest through the Laboratory. The technical areas along Pajarito Road house a significant portion of LANL’s nuclear operations. Existing and planned projects include construction of a new Transuranic Waste Facility, the Material Disposal Area C (MDA-C) closure, and the Material Disposal Area G (MDA-G) closure. Prior to April 2004, Pajarito Road was open to public access. Since that time, access to Pajarito Road has been limited to LANL badgeholders. Pajarito Road, at its intersection with New Mexico State Road 4, had 4,984 average daily vehicle trips in 2004 (DOE/NNSA 2008).

The elevation along Pajarito Road ranges from 6,521 feet to 7,420 feet. The habitat within the general area varies from ponderosa pine on the mesa tops within the higher elevations to piñon-juniper woodlands at the lower elevation. There are open field areas on some mesa tops, and areas of wetlands and riparian habitats at the bottom of Pajarito Canyon. Two-mile Canyon lies to the south of Pajarito Road in the upper (western) part of the Corridor. Pajarito Canyon lies to the south in the central portion of Pajarito Road. In the lower (eastern) portion of Pajarito Road, the road lies in the bottom of Pajarito Canyon. Mortandad Canyon lies to north of Pajarito Road in the upper portion, and Cañada del Buey lies to the north in the lower portion.

Concerns have been raised by the Pueblo de San Ildefonso that LANL operations have created barriers or altered elk movements in such a way that fewer elk are crossing onto tribal property. Pueblo de San Ildefonso property extends west of New Mexico State Road 4 approximately ½ to 1 mile north of Pajarito Road along the eastern half of the road, north of Cañada del Buey. Bennett’s movement model (Figure 2) shows four potential large game movement corridors from LANL to the Pueblo de San Ildefonso property. Of these, two require large game animals to cross Pajarito Road, and an additional corridor is optionally accessed by crossing Pajarito Road.

Model results have identified several large game movement corridors crossing Pajarito Road and three pinch points along the road (Figure 2). The westernmost pinch point is located to the east of Technical Area (TA) 59, in a small drainage area. The next pinch point occurs mainly on the south side of Pajarito Road in TAs 55, 50, 63, and 66. The easternmost pinch point occurs near TA-18 and TA-54 on the south side of Pajarito Road in TA-51.

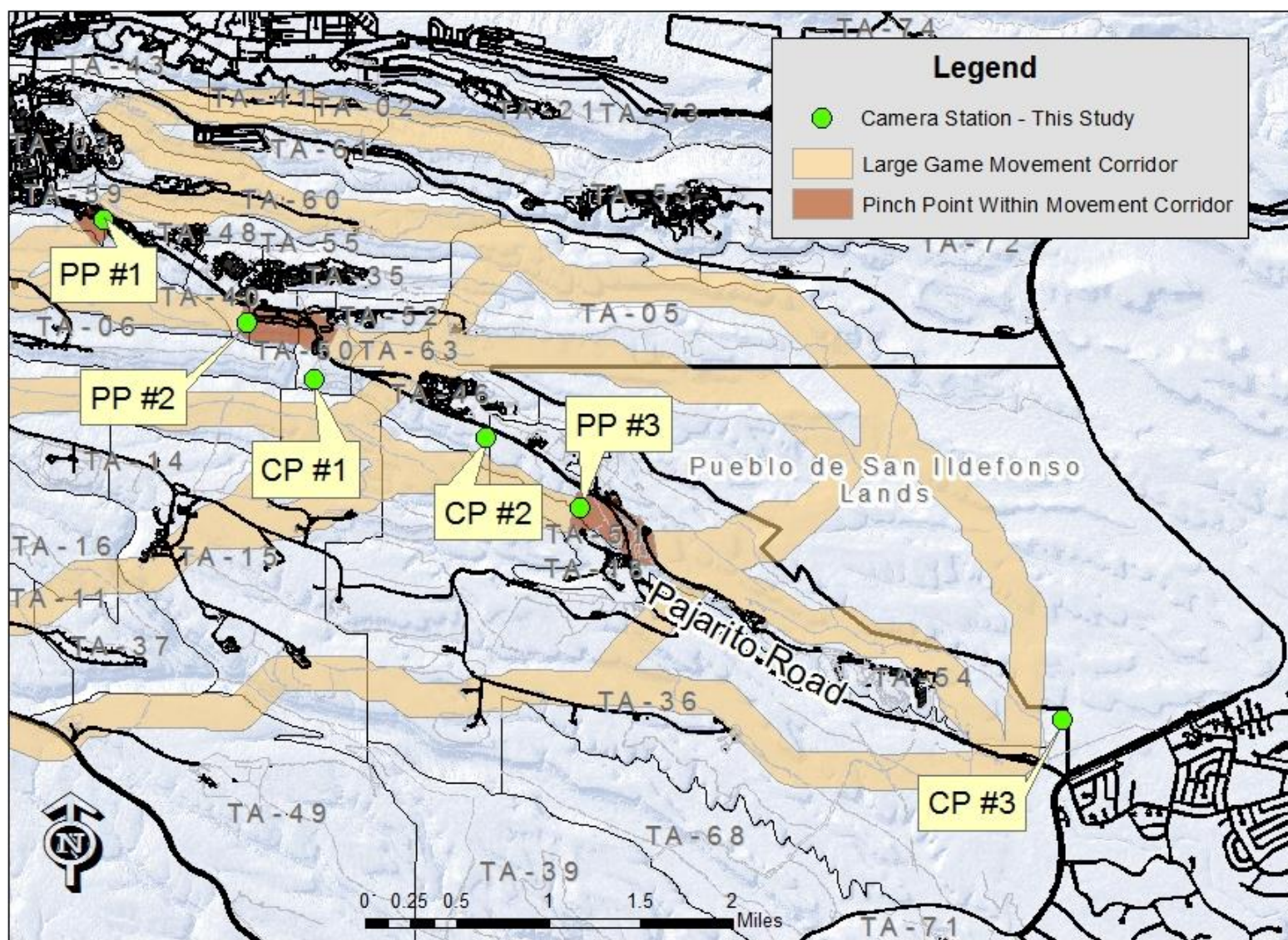


Figure 2. Locations of camera stations along Pajarito Road at Los Alamos National Laboratory. Green marks pinch point (PP) and non-movement-corridor (CP) camera station locations in this study. For display purposes, map shows movement corridors wider than 1,000 feet.

3.0 METHODS

Camera Stations

We used Bushnell® Trophy Cam digital trail cameras to establish six camera stations adjacent to Pajarito Road. These trail cameras are triggered by movement and infrared heat to record photos of passing wildlife. Stations consisted of two cameras mounted directly or indirectly opposing one another. A camera station was placed in each of the three pinch points in areas that had evidence of wildlife use. Three additional camera stations were placed in non-movement-corridor areas as controls. The control camera stations were placed outside of movement corridors but in areas where wildlife encounters were possible (for example, areas potentially used by wildlife for foraging). Figure 2 shows the location of pinch point and control point camera stations.



Figure 3. Picture of wildlife camera installed with t-posts.

Cameras were secured in a protective case with a LANL-issued lock, and secured either to a tree or t-post with a MasterLock® python cable. In some locations t-posts were used to mount the cameras and in other locations trees were used. T-posts were only used in areas where trees suitable for mounting cameras did not exist (Figure 3). Locking the cameras minimized the possibility of camera or memory card theft.

To ensure the cameras would not take photos of any classified actions or property, the camera locations were not placed within any security area and the fields of view of the cameras were not in line of sight of any secured area or activity. In addition, all images were initially screened in the field while downloading images. Any image that had questionable content was deleted. The images were also reviewed and cataloged while uploading to a LANL computer and stored in a database.

The cameras were deployed at the six selected sites in early April 2011. A period of about six weeks was used to test the cameras' operation. At the beginning of the testing period, two cameras were placed at each station and mounted roughly 30 to 50 feet from each other with the camera's field of view facing the other camera. This configuration had mixed results. Many false positive images were obtained. False positive images are images that do not include wildlife

species and usually are caused by wind, rain/snow, insects, or birds landing on vegetation. In most cases, camera configuration was changed so that one camera's field of view would capture images of wildlife moving toward it and the other camera would capture images of the same wildlife moving away from it. Better results were obtained with fewer false positive images.

During the testing period, cameras were checked daily to assess for proper positioning and determine sensor sensitivity settings. Strong winds proved to be a challenge for the camera placement. Branches of trees and shrubs were trimmed, and the cameras were set on the low sensor setting to minimize photos of moving vegetation from high winds. As the spring winds decreased, the cameras were set to the normal sensor setting. During the testing period, cameras were placed at different heights depending on the terrain. Originally, a set height of 1.5 meters from the ground surface was used to mount the cameras. However, terrain within the field of view affected what was visible in the photo. Therefore, camera mounting height was then adjusted based on the surrounding terrain to maximize the field of view of each camera. Even though camera mounting heights differed among the cameras, the field of view was consistent. Camera mounting height was between 3.5 and 4.5 feet for all cameras. Each image showed ground to skyline.

The camera study was officially begun on May 12, 2011, and ended on May 11, 2012. The settings used are in Table 1 (Bushnell Outdoor Technology 2009). Cameras were set to place a date and time stamp on each image as well as the moon phase and the ambient temperature. Cameras were checked weekly. When checking cameras, the status of each camera was recorded in a field log book referenced by the 3-digit property number. The camera's memory card was replaced with a blank card. All memory cards were numbered. The memory card number was recorded for each camera in the field log. Battery life of the camera was checked. Batteries were replaced when battery power was low. The camera settings were verified and the camera was placed back into operation. All details of the camera check were recorded in the field log book by date.

Table 1. Bushnell Trophy Camera Settings

Mode	Camera
Image Size	5M Pixel
Capture Number	3 (selects how many photos are taken in sequence per trigger)
Interval	1 second (selects the length of time that the camera will "wait" until it responds to any additional triggers from the passive infrared (PIR) sensor after an animal is first detected and remains within the sensor's range)
Sensor Level	normal (selects the sensitivity of the PIR sensor. The "High" setting will make the camera more sensitive to infrared (heat) and more easily triggered by motion, and the "Low" setting makes it less sensitive to heat and motion.
Time Stamp	On (select "On" if you want the date and time (that the photo was captured) imprinted on every photo.

Memory cards collected from the cameras were downloaded to a computer and images were stored on an Environmental Protection Division – Environmental Stewardship Services Group (ENV-ES) server. Two persons reviewed each image for the presence of wildlife. Any image that was questionable was further reviewed by additional personnel. The image information was entered in to the BRMP database. Information included date and time of the image, wildlife species, number of animals, sex of the animal (when detectable), and camera station. Only distinct observations were recorded in the database. For example, if a camera took seven images of the same animal, only one record was entered into the database, but all of the images were retained and related to this single record. Time stamps were compared between cameras at the same station to reduce the possibility of double-counting an observation.

Night images required careful attention. In many images, only an eye shine was visible. If an eye shine was detected but nothing else could be distinguished in the image, then the image was enhanced using image-processing software such as Microsoft Office Picture Manager. By adjusting the brightness and contrast, the image of the wildlife was sometimes clearer. In these cases where the image was dark, animal identification was based on animal size, body shape, and, if multiple time series pictures existed, by animal movement.

Accident Locations

We expanded the accident database described in (Biggs et al. 2004) to include accidents from 2000 through 2011. Additional records from the Los Alamos Police Department, the LANL security force, and personal and newspaper reports of animal-vehicle accidents were added to the database of animal-vehicle accidents in Los Alamos County. Where available, we recorded the species involved, the location, date, and time of the accident, cost estimates of damage to vehicles, injuries to humans, and injuries to animals. Accident locations were recorded into the GIS.

Analyses

We began the study with the following testable hypotheses.

- Do animals use pinch point areas more than control areas?
- Are accident locations associated with modeled pinch point locations?
- Are there significant seasonal differences in animal occurrence?

An animal detection was defined as each distinct observation of one or more animals of a particular species. If multiple pictures were taken of an animal or a group of animals that could be identified over time (for example, if an animal laid down within range of a camera), all photographs taken of that animal or group within a 2-hour period were counted as one detection. We calculated the weekly rate of detections of each species photographed per camera station. We also recorded group size for each detection. We tested for normality in the weekly rate data using a Shapiro-Wilks test and a Normal Quantile-Quantile plot. We used a one-sided

Student's t-test to test the hypothesis that detection rates were higher at pinch points than at control points during the period of the study.

We used GIS to examine the occurrence of animal-vehicle accidents within pinch points, within movement corridors crossing Pajarito Road not containing pinch points, and in non-corridor road stretches. We tested the null hypothesis that accidents occurred at proportionally the same frequency in pinch point areas, non-pinch-point movement corridors, and non-corridor locations along Pajarito Road with a Pearson's Chi-Squared goodness-of-fit test.

4.0 RESULTS

Detections of Species at Camera Stations

We recorded nine different species at the camera stations along Pajarito Road. There were a total of 520 detections at the six camera stations, including eight where the species could not be identified. Three species had over 100 detections each: mule deer (*Odocoileus hemionus*; $n = 181$), Rocky Mountain elk (*Cervus canadensis*; $n = 161$), and coyotes (*Canis latrans*; $n = 139$). All other species occurred ≤ 10 times, including mountain lion (*Felis concolor*), bobcat (*Lynx rufus*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), gray fox (*Urocyon cinereoargenteus*), and black bear (*Ursus americanus*).

The only species that had a significant difference in weekly detection rates between pinch point stations and control stations was coyote ($p = 0.041$; Table 2). Coyotes were detected over three times as often at pinch points as at control points. Although the total number of detections of other carnivores was relatively small, bobcats, raccoons, black bears, and grey foxes combined were also observed twice as often at pinch point stations than control stations. Detections of mule deer and elk were relatively evenly distributed between pinch points and control points.

Table 2. Weekly rate of detections for species detected at camera stations located at movement corridor pinch points and at control sites along Pajarito Road, Los Alamos National Laboratory, New Mexico, between 12 May 2011 and 11 May 2012. "Other Carnivores" included black bear, bobcat, raccoon, gray fox, mountain lion, and striped skunk.

Species	Weekly Detection Rates (SD)		P-Value
	Pinch Points ($n = 3$)	Control Points ($n = 3$)	
Mule deer	0.995 (1.084)	1.131 (0.543)	0.572
Elk	0.918 (0.514)	0.918 (0.621)	0.500
Coyote	1.047 (0.521)	0.31 (0.185)	0.041
Other Carnivores	0.207 (0.136)	0.103 (0.129)	0.197

During the period of 27 June 2011 through 8 July 2011, LANL was closed due to the Las Conchas wildfire. The town of Los Alamos was also evacuated for part of this period. Because we continued operating camera stations past the official end date of this study, we had data from 2012 for this same time period. We compared detection rates between 2011 and 2012 to see if the Laboratory closure and/or the large wildfire occurring to the west of LANL property affected animal movements along Pajarito Road. The data set was too small for statistical testing, but there was no suggestion that detection rates were substantially different in 2012 versus 2011 (Table 3).

Table 3. Number of detections and total number of animals counted for elk, mule deer, coyotes, and other carnivores between 27 June and 8 July in 2011 and 2012.

Species	Number of Detections		Total Number of Animals Counted	
	2011	2012	2011	2012
Elk	8	10	30	16
Mule Deer	7	8	12	13
Coyote	2	6	2	6
Other Carnivores	2	3	2	3

For coyotes, mule deer, and elk, we tested for changes in detection rates among seasons. For mule deer and elk, we also tested for changes in average group size among seasons. Since there were no significant differences in detection rates between pinch point stations and control stations for mule deer and elk, we pooled all station data for seasonal analyses of these species. Seasonal data were not always normally distributed, so we used a nonparametric analysis of variance (ANOVA) (Kruskal-Wallis test) for analyses of coyote and deer seasonal data, and a parametric ANOVA for analysis of elk seasonal data. Group size data were also not normally distributed, so we used a nonparametric ANOVA (Kruskal-Wallis test) for analyses of elk and deer group sizes.

There was no evidence of seasonal differences in detections of coyotes at the pinch point stations (K-W statistic = 3.167, $p = 0.53$, $dof = 4$; Figure 5) or control stations (K-W statistic = 7.698, $dof = 4$, $p = 0.103$). Seasonal detections of elk were not significantly different at the $\alpha = 0.05$ level ($F = 2.555$, $p = 0.0638$), although detection rates were at least twice as high in the winter, calving, and summer seasons relative to the spring and fall seasons. Detections of deer did not differ by season (Kruskal-Wallis statistic 4.034, $dof = 4$, $p = 0.401$). Both deer and elk showed evidence of group sizes varying by season, although elk differences were not significant at the $\alpha = 0.05$ level (deer, Kruskal-Wallis statistic = 9.963, $dof = 4$, $p = 0.0411$; elk, Kruskal-Wallis statistic = 7.986, $dof = 4$, $p = 0.0921$; Figure 6).

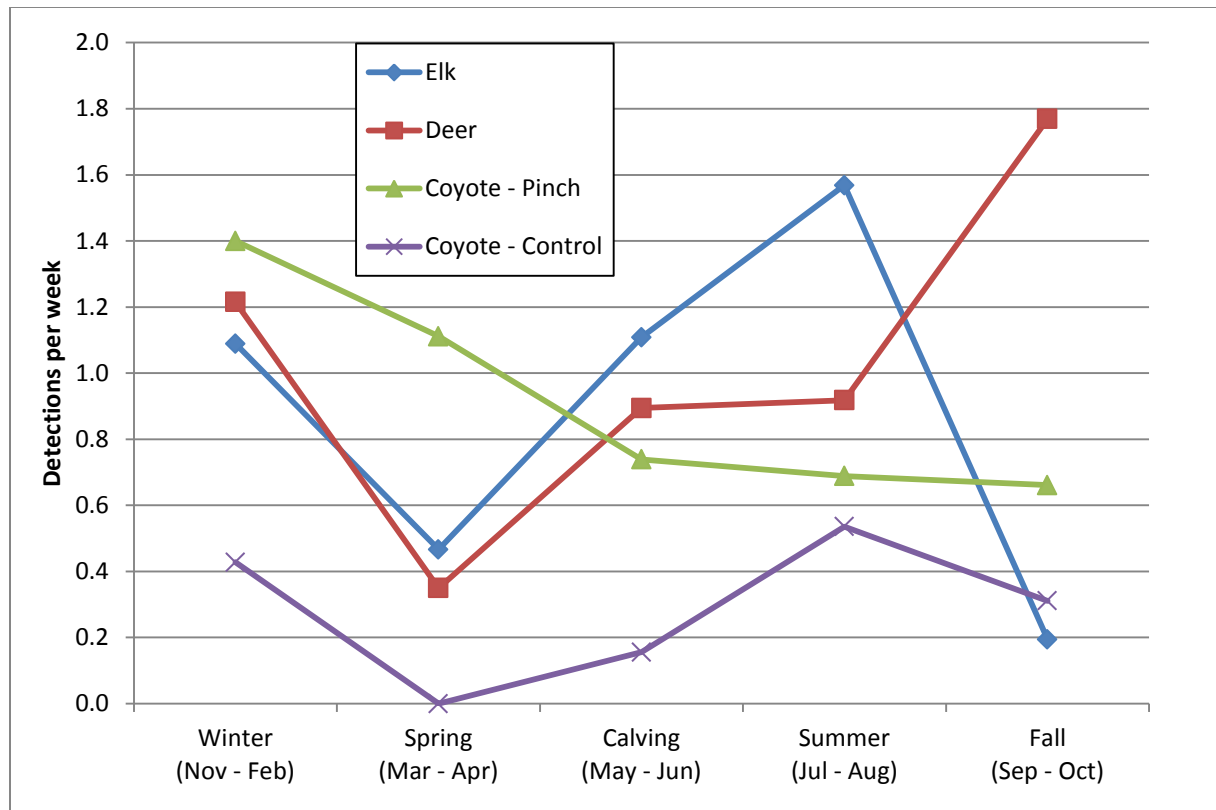


Figure 5. Seasonal detection rates for mule deer, Rocky Mountain elk, and coyote at camera stations along Pajarito Road, Los Alamos National Laboratory, New Mexico, May 2011–May 2012.

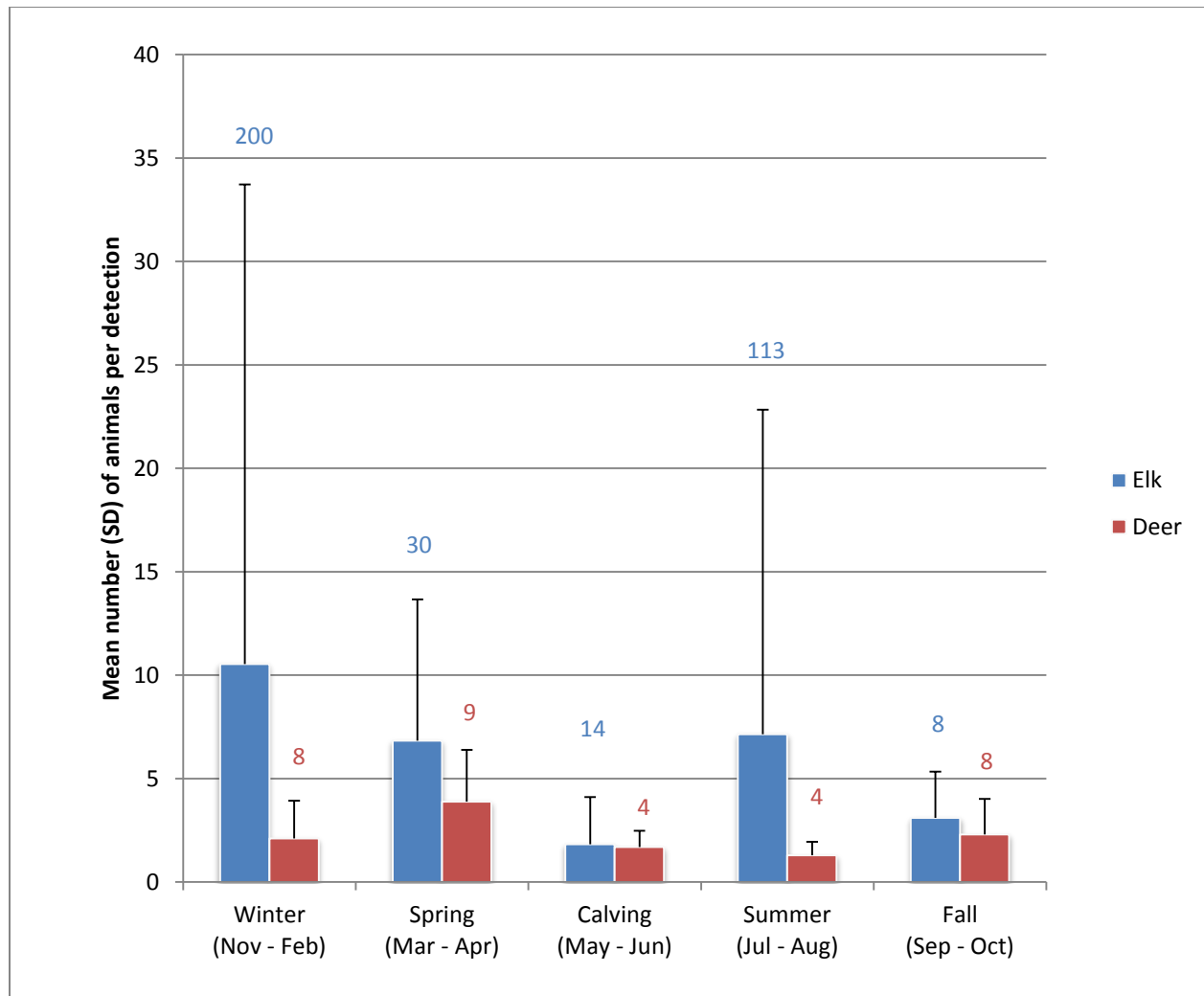


Figure 6. Mean seasonal group sizes of elk and deer detected at camera stations along Pajarito Road, Los Alamos National Laboratory, New Mexico, May 2011–May 2012. Error bars represent the positive standard deviation, and the number above each bar represents the maximum group size recorded for that species in that season.

We photographed elk with young calves and deer with fawns (Figure 7), demonstrating that elk and deer are using the area near Pajarito Road for raising young. There were a total of 31 detections of elk and 37 detections of deer during the calving season along Pajarito Road (see charts of elk and deer occurrences during calving season versus other seasons, Appendix A). Use of the Pajarito Road area during calving season was common for both elk and deer.

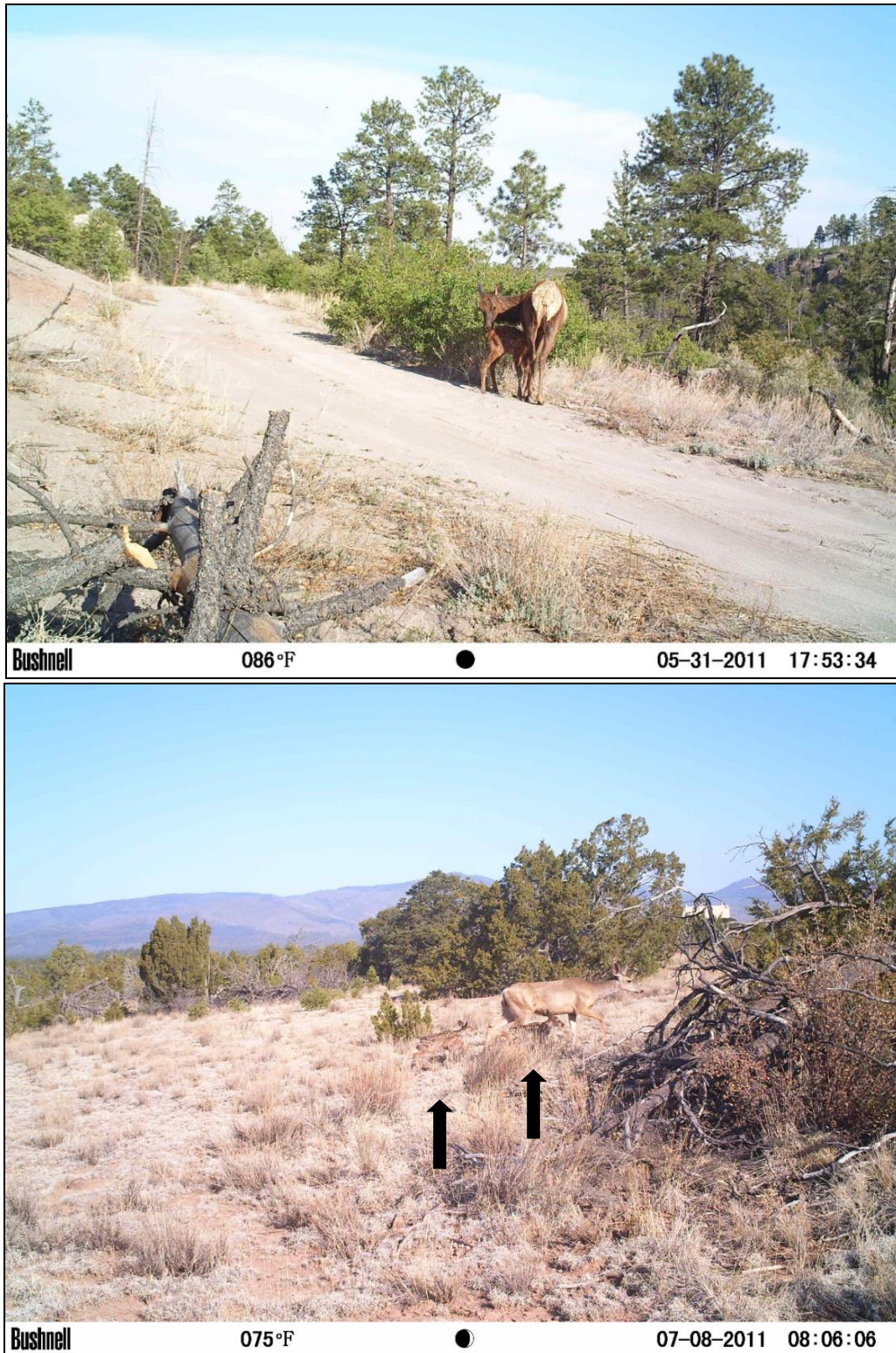


Figure 7. Photographs from camera stations of elk with nursing young (top) and mule deer with twin spotted fawns (bottom). Black arrows point at the fawns in the photograph.

Animal-Vehicle Accidents

We analyzed the locations of 98 animal-vehicle accidents that occurred along Pajarito Road from 1990 through July 2011 (data was not available for 2003 and 2004). Animal-vehicle accidents in Los Alamos County most commonly involve mule deer, with elk as the second most commonly involved species (Biggs et al. 2004). For Pajarito Road, 70.3 percent of the road is not within an identified movement corridor. Pinch point locations cover 17.4 percent of Pajarito Road, and non-pinch-point corridors cover 12.3 percent of Pajarito Road.

Of the 98 accidents, 56 percent (55 accidents) occurred outside of any movement corridor, 30 percent (29 accidents) occurred within pinch points, and 14 percent (14 accidents) occurred within non-pinch-point movement corridors (Figure 8). A Pearson's chi-squared goodness of fit test found that the distribution of accidents along Pajarito Road was not random with respect to movement corridors ($\chi^2 = 11.49$, $p = 0.0032$). There were more accidents than expected associated with pinch points, and fewer accidents than expected associated with non-movement-corridor locations.

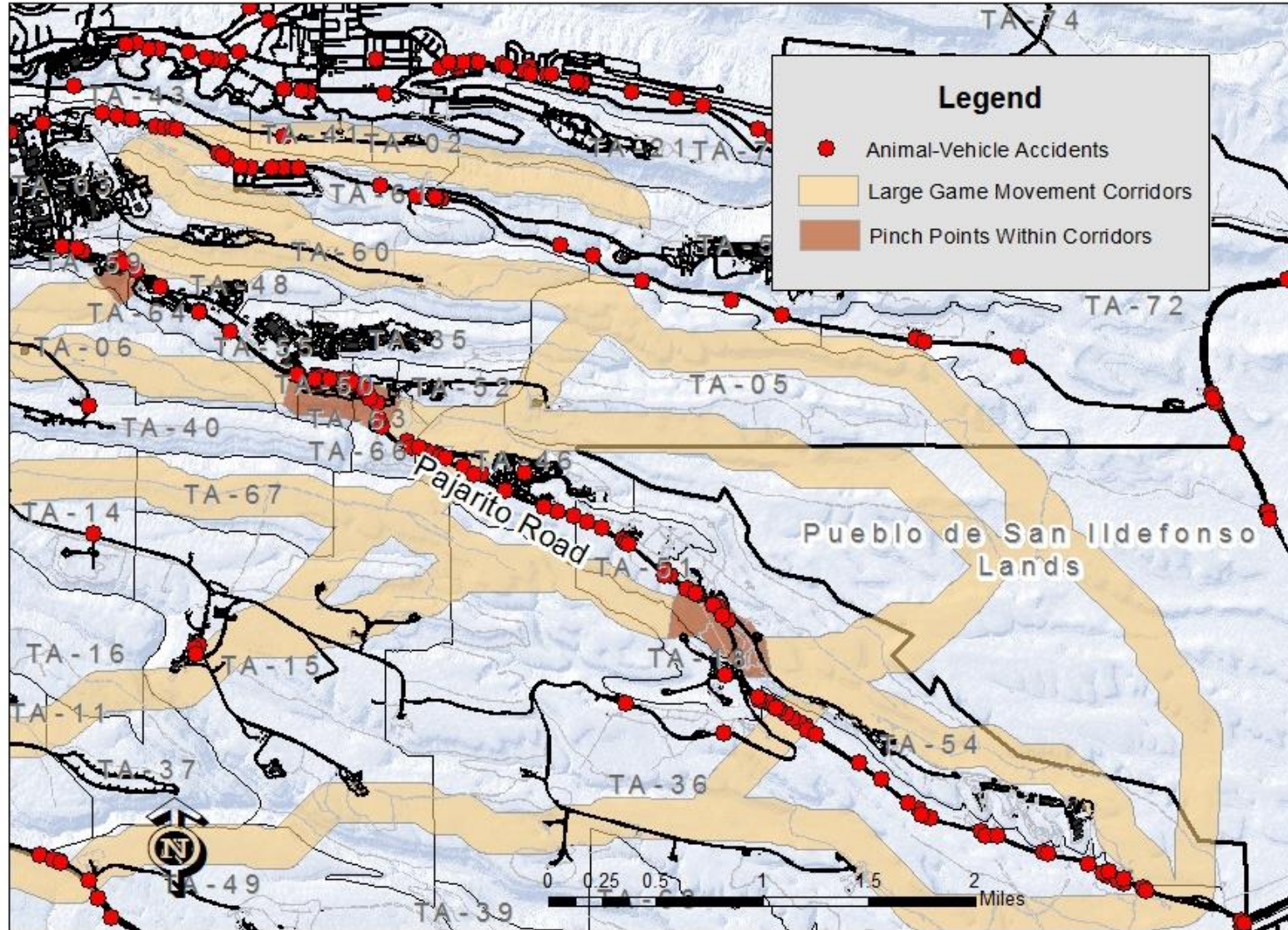


Figure 8. Map showing locations of animal-vehicle accidents along Pajarito Road from 1990 through 2011 in relation to predicted large game movement corridors.

Photo Station near the LANL-Pueblo de San Ildefonso Boundary

We compared the annual detection rates of animals at the Pajarito Road Control Point #3 (CP #3), which was located north of Pajarito Road near the Pueblo de San Ildefonso boundary, but outside of a movement corridor, to the detection rates measured at our other camera stations (see Figure 2) between May 2011 and May 2012 (Table 4).

Table 4. Average weekly detection rates of animals at pinch point camera stations, control point camera stations 1 and 2, and detection rates at control point camera station 3 at Los Alamos National Laboratory, New Mexico, between 12 May 2011 and 11 May 2012. Control Point Station #3 was located near the LANL-Pueblo de San Ildefonso boundary.

Species	Weekly Detection Rates (SD)		
	Pinch Points (n=3)	Control Point Station #1 and #2	Control Point Station #3
Mule deer	0.995 (1.084)	1.144 (0.768)	1.108
Elk	0.918 (0.514)	1.173 (0.617)	0.407
Coyote	1.047 (0.521)	0.417 (0.014)	0.097
Other Carnivores	0.207 (0.136)	0.136 (0.165)	0.039

Mule deer were detected at the camera station near the LANL-Pueblo de San Ildefonso boundary (CP #3) at about the same rate they occurred at all other Pajarito Road stations. Other species (elk, coyotes, and other carnivores) were detected less frequently at CP #3 than at other stations.

CP #3 is considerably east of the other photo stations, entirely in piñon-juniper habitat, and is not adjacent to a deep canyon, unlike the other photo stations. Our results suggest that this location may be less attractive to elk and carnivores than other areas adjacent to Pajarito Road further west. However, the detections of elk and deer here suggest that large game are not excluded from this area by LANL operations.

Discussion

In this study, corridor pinch points did not predict the locations where we would observe more deer or elk when compared to non-pinch point areas. Our camera stations were set up near, but out of sight of, Pajarito Road. Pinch points were developed from portions of movement corridors where the corridor was constricted or funneled. The movement corridors in this study were developed by predicting direct animal movement from a source area to a receiving area. The corridors take into consideration not only the cost of barriers and the suitability of habitat but also distance by assuming that with all other things being equal, lower impedance is given to the shortest distance. When a corridor hits an area where there is ample forage and resident animals, an animal using the corridor may elect to wander and forage rather than travel on a

direct route. In addition, there were several movement corridors along the Pajarito Road corridor that did not contain pinch points. These corridors were not tested for increased use.

Our photographic evidence suggests that at least some elk and deer were resident in the area. For most of its length, Pajarito Road is located either on a mesa top or in the bottom of a wide canyon, with flat or moderately sloped woodland habitat on either side of the road. Our results suggest that locally moving animals did not have a preference for the pinch point locations, and were using the entire habitat around Pajarito Road on a relatively equal basis.

The movement corridor modeling did take into account the relative cost of the corridor cells and surrounding non-corridor cells. However, the increased cost or impedance of non-corridor cells within the forage area along Pajarito Road was small compared to the impedance values within the movement corridor. Instead of applying a constant distance buffer (1,000 feet) to the corridor, a threshold impedance could be applied to include areas into the corridor that cross forage areas where impedance only increases as a factor of distance. Segments of the corridor can have similar cost to adjacent areas especially if there are wide areas of foraging habitat such as seen adjacent to Pajarito Road.

Despite the lack of observed preference for pinch points by elk and deer along Pajarito Road, the evidence suggests that the pinch points do have value in predicting animal movements. Pinch points located on Pajarito Road had more animal-vehicle accidents than expected by chance. Coyotes and other carnivores were more likely to be detected at pinch point locations than at non-movement corridor locations. Possibly animals that are climbing in and out of the canyons on either side of Pajarito Road have a greater probability of being detected in the movement corridor locations.

The camera study results demonstrated that large game animals are present in the Pajarito Road area year-round, that elk and deer are calving or fawning and raising young in the area, and that large game and carnivores apparently move freely around and along Pajarito Road. We did not find any evidence suggesting that the presence of LANL-related roads or facilities is preventing the movement of large game from LANL property onto Pueblo de San Ildefonso property.

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Appendix A: Supplemental Data. Number of detections of elk and deer by season at pinch point camera stations and control camera stations.

Total Number of Occurrences by Site/Season and Species

Seasonal	CALA	CEEL	FECO	LYRU	MEME	ODHE	PRLO	UNKNOWN	URAM	URCI
Spring CP1	0	4	0	0	0	1	0	0	0	0
Spring CP2	0	3	0	0	0	2	0	0	0	0
Spring CP3	0	0	0	0	0	2	0	0	0	0
Spring PP1	16	3	0	0	0	1	0	0	0	0
Spring PP2	13	0	0	0	0	1	1	0	0	0
Spring PP3	1	0	0	0	0	6	0	0	0	0
Total Spring	30	10	0	0	0	13	1	0	0	0
Calving CP1	3	13	1	0	0	0	0	0	0	0
Calving CP2	0	2	0	0	0	5	0	0	0	0
Calving CP3	0	0	0	0	0	8	0	0	0	0
Calving PP1	10	6	0	0	1	15	1	0	1	2
Calving PP2	6	2	0	0	0	1	0	0	0	0
Calving PP3	1	8	0	0	0	8	0	0	0	0
Total Calving	20	31	1	0	1	37	1	0	1	2
Summer CP1	0	13	0	0	0	4	0	0	0	0
Summer CP2	0	0	0	0	0	1	0	0	0	0
Summer CP3	1	1	0	1	0	9	0	2	0	0
Summer PP1	2	13	0	0	0	2	1	0	1	0
Summer PP2	7	20	0	0	0	0	0	1	1	0
Summer PP3	4	6	0	0	0	10	0	0	1	0
Total Summer	14	53	0	1	0	26	1	3	3	0
Fall CP1	0	1	0	0	0	2	0	0	0	0
Fall CP2	3	2	0	0	0	14	0	0	1	0
Fall CP3	0	2	0	1	0	21	0	2	0	0
Fall PP1	3	0	0	0	0	8	1	0	4	0
Fall PP2	3	0	1	0	0	0	1	0	0	0
Fall PP3	4	2	0	0	0	9	0	0	0	0
Total Fall	13	7	1	1	0	54	2	2	5	0
Winter CP1	5	13	1	0	0	4	0	1	0	0
Winter CP2	4	13	0	0	0	20	0	0	0	0
Winter CP3	1	12	0	0	0	2	0	1	0	0
Winter PP1	34	2	0	1	0	3	2	1	1	1
Winter PP2	18	0	0	3	0	2	0	0	0	0
Winter PP3	0	20	0	1	0	20	0	0	0	0
Total Winter	62	60	1	5	0	51	2	3	1	1
CP Total	17	79	2	2	0	95	0	6	1	0
PP Total	122	82	1	5	1	86	7	2	9	3

Appendix B: Photos from study camera stations



Pinch Point 1. Black bear



Control Point 2. Mule Deer Buck



Pinch Point 1. Bobcat



Control Point 1. Rocky Mountain Cow Elk



Control Point 1. Rocky Mountain Cow Elk



Control Point 1. Rocky Mountain Elk



Pinch Point 1. Coyotes (Note: The time stamp malfunctioned on the camera for this period. This photo was taken in June of 2011.)



Control Point 2. Rocky Mountain Elk (Note: The time stamp malfunctioned on the camera for this period. This photo was taken in August of 2011.)



Control Point 3. A mule deer with the Las Conchas fire in the background



Control Point 2. Grey Fox



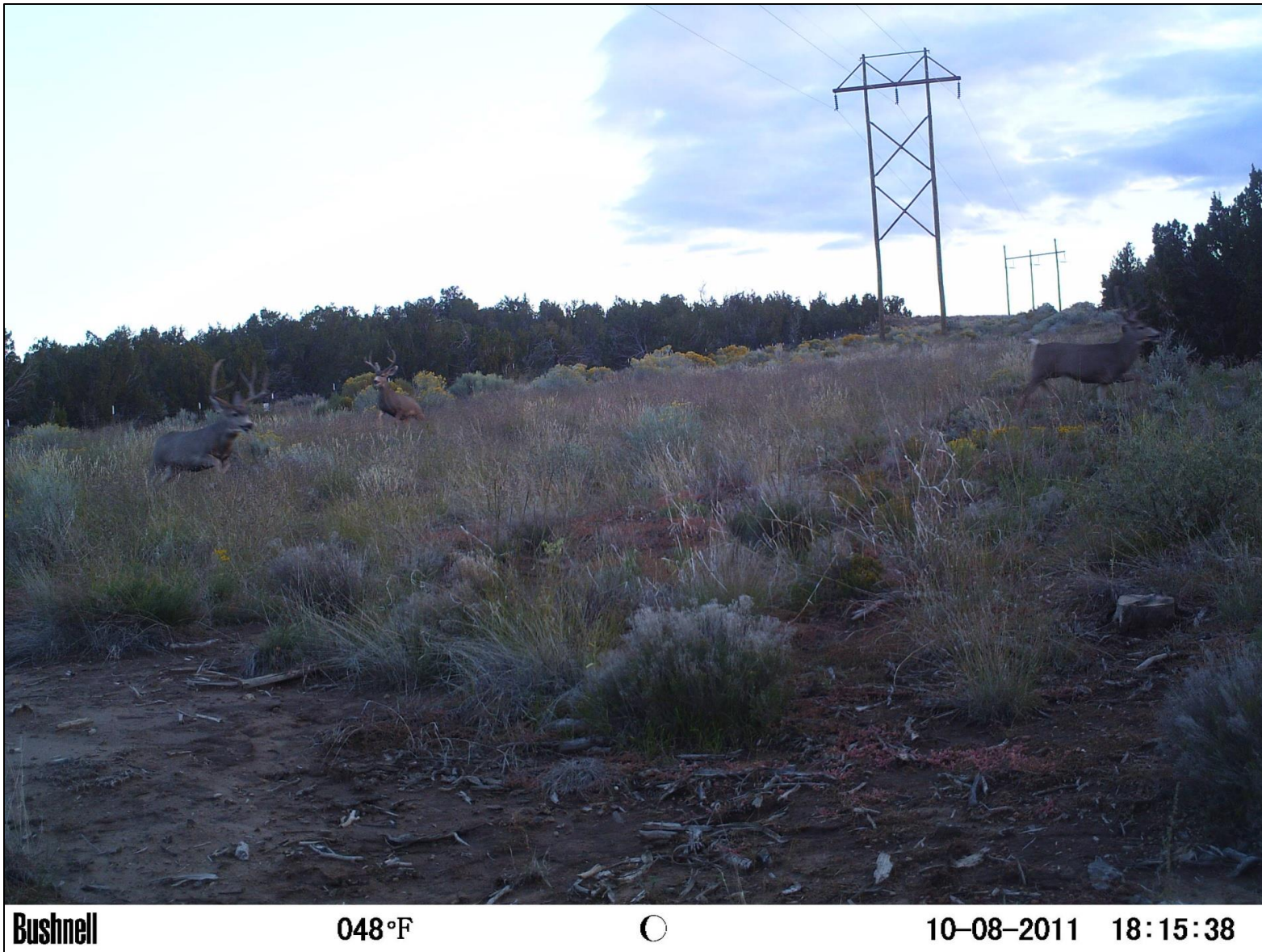
Control Point 3. Rocky Mountain Bull Elk



Pinch Point 1. Mule deer does and fawns



Pinch Point 1. Black Bear



Control Point 3. Mule Deer Bucks



Control Point 3. Mule Deer Buck



Pinch Point 1. Rocky Mountain Elk, bull and calf



Pinch Point 1. Rocky Mountain Elk calf



Control Point 2. Mountain lions